DISCRIMINATED TIMEOUT AVOIDANCE IN PIGEONS: THE ROLES OF ADDED STIMULI

ANTHONY DeFULIO AND TIMOTHY D. HACKENBERG

UNIVERSITY OF FLORIDA

Two experiments examined pigeons' postponement of a signaled extinction period, or timeout (TO), from an ongoing schedule of response-dependent food delivery. A concurrent-operant procedure was used in which responses on one (food) key produced food according to a variable-interval schedule and responses on a second (postponement) key delayed the next scheduled TO according to a response–TO (R–TO) interval. A series of response-independent stimulus changes on the food key temporally partitioned the R–TO into three equal segments (S1, S2, and S3). Postponement responses, in addition to postponing TO, also reinstated S1, the stimulus correlated with the greatest temporal distance from TO. In Experiment 1, the R–TO interval was manipulated systematically across blocks of sessions (conditions) at a given ratio of R–TO:TO duration. This R–TO:TO ratio was manipulated across blocks of conditions (phases). Postponement response rates varied inversely with R–TO interval in each phase. Changes in the R–TO:TO ratio did not produce consistent differences except at the 1:10 ratio for some pigeons, where it disrupted postponement responding in some conditions. Most of the postponement responses occurred in the presence of S2 and S3, the stimuli most proximal to TO, whereas most of the food-key responses occurred in S1. In Experiment 2, the R–TO contingencies were systematically manipulated in the presence of the time-correlated stimuli. In one set of conditions, the R–TO contingencies were made either ineffective or less effective in the presence of one or more stimuli. Postponement responses typically shifted to stimuli in the presence of which responses were relatively more effective. Postponement responses decreased markedly when the added stimuli were removed, and then recovered when the stimuli were reinstated. Results from both experiments indicate that the added stimuli in a discriminated TO-avoidance procedure serve predominantly discriminative functions, delineating periods during which behavior is maximally effective. The results parallel those obtained in shock-avoidance procedures, providing further evidence that TO functions as an aversive stimulus.

Key words: discriminated timeout-avoidance, warning stimuli, concurrent operants, key peck, pigeon

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Timeout (TO) from reinforcement can be defined as a signaled extinction period, and has been shown to function as an aversive stimulus under a variety of conditions (Leitenberg, 1965). Perhaps the most compelling evidence of the aversive functions of TO come from free-operant (Sidman) avoidance procedures, in which responses postpone TOs from an ongoing schedule of positive reinforcement. With electric shock as the aversive event, response rate varies as an inverse function of the response–shock (R–S) interval, the period of time by which a response postpones the next shock (Clark & Hull, 1966; Sidman, 1953). So, too, in procedures employing TO instead of shock, postponement response rates increase as the interval between responses and

TO (R–TO) decrease (D'Andrea, 1971; Ferster, 1958; Galbicka & Branch, 1983; Morse & Herrnstein, 1956; Thomas, 1965).

In Ferster's (1958) experiment, for example, chimpanzees' responses on one key were reinforced according to a variable-interval (VI) schedule, in which responses produced food every 180 s, on average. A TO–TO interval of 45 s was arranged such that in the absence of responding, TOs occurred every 45 s. Responses on a second key postponed a 180-s TO according to an R–TO interval, the duration of which varied systematically across conditions from 60 to 600 s. Responding on the avoidance key was sufficient to postpone most TOs, with rate of avoidance behavior varying inversely with R–TO interval.

Discriminated free-operant avoidance procedures provide an additional context in which to assess the aversive functions of TO. These procedures are in most ways identical to nondiscriminated avoidance procedures except that they also include a preaversive (warning) stimulus correlated with the presentation of the aversive stimulus (Sidman & Boren, 1957a). Such stimuli have important

effects that are largely determined by their relationship to the aversive stimulus.

With shock as the aversive event, responding tends to gravitate toward stimuli proximal to shock. Sidman and Boren (1957a), for example, superimposed a 5-s preshock (warning) stimulus on a free-operant postponement procedure, such that a response in the presence of the stimulus both terminated the stimulus and postponed the upcoming shock. A response prior to the warning stimulus postponed both the stimulus and the shock. Rats were more likely to respond in the presence of the stimulus than in its absence. When avoidance responses were made ineffective in the presence of the warning stimulus, responding shifted earlier in the cycle, prior to the warning stimulus.

In a similar vein, Field and Boren (1963) arranged a situation in which warning stimuli changed as time to shock drew nearer. When no time-correlated stimuli were available, rats responded at rates sufficient to keep the onset of shock temporally distant. When both auditory and visual time-correlated stimuli were associated with the onset of shock, however, responding typically occurred in greater proximity to shock. Taken together, the results of these two studies suggest that added stimuli in free-operant avoidance procedures serve important discriminative functions, delineating periods of maximally efficient avoidance behavior.

Thomas (1965) found generally similar effects with TO as the putatively aversive event. He investigated the effects of R–TO interval and TO duration in a discriminated TO-avoidance procedure with time-correlated (warning) stimuli with pigeons. Concurrent avoidance and food schedules were arranged. Pecks on one key produced food according to a variable-ratio (VR) 140 schedule of reinforcement. Pecks on a second key postponed TOs according to a R–TO interval, the duration of which varied systematically across conditions. The R–TO interval was split into four equal segments, across which the color of the food key changed as TO drew nearer. A single peck on the avoidance key reset the R–TO and restored the key color associated with the greatest temporal distance from TO. In one series of conditions, TO duration was varied from 30 to 900 s while the R–TO interval was held constant at 60 s.

Consistent with other findings on avoidance procedures with both shock and TO, rate of avoidance responding was an inverse function of the R–TO interval for both pigeons studied. The function relating avoidance response rates to TO duration was curvilinear: Responding was maintained at moderate levels under TO durations of 30 and 120 s, peaked at 300 s, then dropped to low levels at 900 s. Thomas also analyzed the temporal distribution of avoidance responding within and across R–TO intervals. In most cases, responding was highest in the presence of stimuli proximal to TO.

Together, the effects of R–TO interval, TO duration, and the temporal distribution of avoidance behavior reported by Thomas (1965) are broadly consistent with results of comparable studies with electric shock as the aversive stimulus, and provide a convincing demonstration of the aversive functions of TO in free-operant avoidance procedures. The study had some limitations, however. To begin with, only 2 subjects were studied, and although the effects were generally comparable, there was a fair degree of between-subject variability that complicates interpretation. Second, the effects of TO duration were studied only briefly and in the context of a single R–TO interval.

One aim of the present study was to extend the Thomas (1965) study with a larger number of subjects and in the context of a more extensive parametric investigation. In Experiment 1, the R–TO intervals and TO durations were varied separately and together across conditions, yielding four distinct R–TO:TO ratios. These ratios constituted experimental phases, each composed of three R–TO intervals and an extinction condition, in which the postponement contingency was disabled.

A second aim was to determine more precisely the functions of added stimuli in TO-avoidance procedures. In both experiments, we examined the temporal distribution of postponement responses in relation to the time-correlated stimulus changes superimposed on the postponement contingencies. In Experiment 2, we explicitly manipulated contingencies in the presence of the time-correlated (warning) stimuli, replicating some of the key conditions from Sidman and Boren's (1957a, b) studies, but with TO instead of shock as the aversive stimulus. In

other conditions of Experiment 2, we compared discriminated to nondiscriminated TO-avoidance performance. Together, the two experiments considerably expand the data base on TO avoidance, adding much needed parametric data on R–TO interval, TO duration, as well as data on acquisition and extinction. The experiments also provide a clearer picture of the role of added stimuli in TO-avoidance procedures.

EXPERIMENT 1
METHOD

Subjects

Five male White Carneau pigeons (*Columba livia*), maintained at approximately 80% of their free-feeding body weights, served as subjects (611, 626, 910, 1046, 2875). All pigeons were approximately 4 years old at the start of the experiment, with the exception of Pigeon 626, who was approximately 3 years old. Pigeon 611 died in the early stages of Experiment 1 and was replaced with Pigeon 626. Thus, data for Pigeon 611 are not reported. The pigeons had served previously in an undergraduate laboratory class but were naive with respect to the present procedures. The pigeons were housed in individual cages in a colony room where they had free access to water and grit. The colony was kept on a light/dark cycle with a light duration of 16.5 hr, with the light cycle beginning at 7 AM.

Apparatus

Sessions were conducted in a standard three-key operant chamber. The experimental space measured 30.5 cm long, 35 cm wide, and 35 cm high. Keys were arranged 23.5 cm from the floor of the chamber and were spaced 5.7 cm apart. Only the left and center keys were used; the right key was removed and the opening was sealed with a small piece of aluminum of similar thickness to the intelligence panel. A houselight located 4.5 cm above the center key provided general illumination in the chamber. A solenoid-operated food hopper was used to deliver 3-s access to mixed grain. Response keys required a force equal to or in excess of 0.12 N to register a response. The left key was illuminated with either a yellow, green, or red light, depending on the temporal proximity to TO. The order of presentation of key colors was varied across

subjects but was consistent throughout the experiment for each subject. The center key was illuminated white for all subjects across all conditions. All experimental events were controlled and data collected by a standard PC using MED-PC IV© software.

Procedure

Initial training. Session duration was 60 min throughout the entire experiment. Initially, pecks on the left (food-production) key produced food according to a VR 140 schedule during 30-s timein (TI) periods, signaled by the illumination of the left response key. These TI periods alternated with 300-s TO periods, during which the left response key was dark. Key color on the food key changed every 10 s. When response rates stabilized, the center (postponement) key was introduced. Initially, the R–TO was set at 30 s and the center key was operable during both TI and TO, permitting both escape (if responses occurred during TO) and postponement (if responses occurred during TI). This arrangement failed to produce consistent responding on the postponement key. To reduce competition between the food and postponement keys, the food schedule was changed to a VI 120-s schedule, and subsequently leaned to VI 360-s. When extended exposure to this arrangement produced behavior in the presence but not the absence of TO, we undertook two manipulations that were designed to facilitate avoidance behavior. First, the houselight was darkened during TO periods to enhance discriminability. Then, across a series of conditions, we gradually reduced the availability of the center key during TO periods. This was accomplished by reviewing the distribution of latencies from the onset of TO to an escape response every 3 to 5 days, and setting the duration of availability of the center key during TO periods to a value that captured only the shortest one-third of the latency distribution. As the duration of center-key availability was shortened, responding shifted such that some of the responses to the center key occurred before the onset of TO. Once approximately one-third of the responses to the center key were occurring before the onset of TO, the center key was made unavailable during TO.

General procedure. A concurrent food–TO-avoidance procedure was arranged in which

pecks on the left key produced food according to a VI 360-s schedule and pecks on the center key postponed periodic timeouts from the food schedule according to an R–TO schedule. Due to early difficulties establishing avoidance behavior in Pigeon 2875, the schedule on the food key was changed from VI 360-s to VI 240-s for this subject only, where it remained for the duration of the experiment.

The R–TO requirements varied systematically across conditions. In the absence of center-key (TO-postponement) responses, TOs were scheduled to occur at fixed times according to a TO–TO interval, the value of which was equal to the R–TO interval across conditions. A series of time-correlated stimulus changes was arranged on the food key, whereby the key color changed when one-third of the interval had expired (R–TO or TO–TO, depending on whether the initiating event was a response or a TO, respectively). A single peck on the center (TO-postponement) key reset the R–TO interval and produced the key color correlated with the greatest temporal distance from timeout (S1). Failure to peck the postponement key during the R–TO or TO–TO interval produced a timeout.

During TO the houselight and response keys were darkened and the VI food schedule was suspended. Responses during TO were counted but were ineffective in reinstating timein. A 3-s changeover delay (COD), timed from the last occurrence of a center-key (postponement) response, prevented reinforcement of left (food) key pecks immediately following a postponement response. This COD was put in place in the condition immediately preceding the beginning of Experiment 1 for all pigeons except 910. Due to an experimenter error, the COD was not instituted for Pigeon 910 until the beginning of Phase 2.

The primary independent variables of interest were R–TO interval and TO duration, which were manipulated systematically across blocks of experimental sessions, or conditions. The ratio of R–TO duration to TO duration (hereafter, R–TO:TO) was manipulated across blocks of conditions, or experimental phases. Across phases, R–TO:TO ratios of 1:1, 1:2, 1:5, and 1:10 were studied. The sequence of exposure to these ratios was identical for all pigeons. Across conditions within a phase, R–

TO values of 15, 30, and 60 s were studied in the context of three TO durations. Each phase also included an extinction condition, during which postponement responses had no effect on TO or the time-correlated stimuli. At least one replication of a condition from each R–TO:TO series was accomplished. Thus, each phase typically consisted of five conditions: three R–TO values, extinction, and one replication. Order of conditions, number of sessions, and R–TO and TO durations in each condition are shown in Table 1. Pigeon 626 died after completing three of four phases.

Conditions remained in effect for at least 10 sessions and until daily postponement response rates were deemed stable via visual inspection. A judgment of stability required the absence of trend across five sessions and that neither the highest nor lowest points of the condition were included in those sessions. This latter requirement was removed for extinction conditions. Exceptions occurred in some early extinction conditions in which fewer than 10 sessions were conducted. These exceptions were due to the apparent fragility of the avoidance performance (see *Initial training*). Once responding recovered after several extinction conditions, however, the minimum session requirement assumed the more stringent definition above.

An additional condition type was run for Pigeon 626 due to unusually high response rates on the postponement key in two extinction conditions. To examine the possibility that behavior was maintained by relatively contiguous food presentations, the COD was lengthened first to 10 s, and subsequently to 20 s, with experimental parameters otherwise identical to those in place during extinction conditions. The COD was then reduced to the standard of 3 s for subsequent conditions.

Results

Figure 1 shows mean response rates on the TO-postponement key as a function of R–TO interval for each pigeon across the final five sessions in each R–TO condition, and the final session from each extinction condition (see Table 1 for standard deviations). Each data path represents results from a single R–TO:TO ratio. Postponement response rates typically varied inversely with R–TO interval for all pigeons across all phases. Two exceptions to this finding were observed. First, Pigeon 1046

pecked the postponement key at a lower rate during the R–TO 15 s condition than during the R–TO 30 s condition of the 1:10 phase. A later replication of this condition produced a lower rate of responding to the postponement key than the initial exposure, as did replications of the R–TO 30 s condition for this phase. Second, during the 1:2 phase, Pigeon 626 pecked the postponement key at a higher rate during the R–TO 60 s condition than during both the R–TO 30 s and R–TO 15 s conditions. Despite these exceptions, however, postponement responding for Pigeons 1046 and 626 usually followed the same pattern observed for other pigeons, with response rates decreasing as the R–TO interval was increased.

Responding on the postponement key occurred at low levels in Extinction (EXT) conditions, when such responses were ineffective. The lone exception to this general finding was for Pigeon 626. This pigeon responded similarly to the others during the initial exposure to an EXT condition (R–TO:TO = 1:5) but subsequent exposures to extinction conditions produced higher rates on the postponement key than those obtained during the prior postponement conditions. The extended COD conditions, described above, reduced but did not eliminate entirely postponement responding. Rates returned to their previous high levels when the standard COD was reinstated. Unfortunately, this pigeon died before this experiment was completed.

Figure 2 shows avoidance proficiency, defined as the percentage of TOs avoided, as a function of R–TO interval, over the final five sessions per conditions for each pigeon. The pigeons avoided a high percentage of scheduled timeouts, usually spending greater than 80% of the sessions in TI. The main exceptions occurred at some of the higher R–TO:TO ratios, where for 3 pigeons avoidance proficiency decreased. In some cases, the functions relating avoidance proficiency to R–TO interval were more graded in these conditions as well, with longer R–TO intervals resulting in greater percentage of TOs avoided.

Data were analyzed further to determine how postponement responses were distributed through time and in relation to the time-correlated key-color changes. Because responses early in an R–TO interval precluded responses later in that interval, we analyzed the temporal distribution of postponement responding corrected for opportunity. Figure 3 shows the postponement responses per opportunity in the presence of each stimulus for each pigeon across the last five sessions in each condition. For ease of exposition these stimuli are referred to by their temporal order rather than by their color: S1 (furthest from TO) and S3 (closest to TO). Responses were least likely in the presence of S1. Most of the postponement responses occurred in the presence of S2 and S3, the stimuli more proximal to TO.

The stimulus in the presence of which postponement responses were most probable varied across subjects. For Pigeon 910, postponement responses were most likely in the presence of S3 across all conditions. Similarly, for Pigeon 2875, response probability was almost always highest in S3, but there was a substantial tendency for this pigeon also to respond in S2—a tendency that increased with R–TO value. For example, in the R–TO 60 s condition of the 1:5 Phase, Pigeon 2875 showed a higher probability of a postponement response in the presence of S2. For Pigeons 626 and 1046, response probability was usually highest in the presence of S2. There was also some tendency for these pigeons to respond in S3, but these occasions rarely occurred, as S2 responses reset the R–TO interval.

Figure 4 shows the proportion of food deliveries in the presence of each of the time-correlated stimuli for all pigeons across all conditions. Food deliveries were consistently highest in the presence of S1 (41 of 45 cases, across all 4 pigeons), the part of the cycle when postponement responding was least frequent. When postponement responding was ineffective (EXT), the distribution of food-key responding spread to S2 and S3 (not shown in the figure). Response rates on the food key in the presence of each stimulus, as well as total time spent in the presence of each stimulus across all conditions of Experiment 1, are presented in Appendix A.

DISCUSSION

On the whole, the present results replicate and extend prior findings by Thomas (1965), the only other parametric within-subject analysis of discriminated TO avoidance. The

Table 1

Number of sessions per condition, response rates (SD) on food key and postponement key, and the percentage of TOs avoided (SD) over the final five sessions of each condition for each pigeon in Experiment 1.

Pigeon	Phase/Condition	Sessions	Resp/min Food Key	Resp/min Post Key	% TO Avoided
2875	1:5				
	R-TO=30[a]	26	46.5 (2.4)	3.6 (0.1)	92.0 (9.7)
	R-TO=15	13	36.6 (4.3)	6.1 (0.1)	90.0 (4.7)
	R-TO=60	19	45.4 (5.1)	2.2 (0.1)	92.0 (13.0)
	R-TO=30	12	42.8 (2.8)	3.5 (0.2)	95.0 (5.0)
	TO-TO=30	14	14.5	0.2	
	1:2				
	R-TO=30	25	42.4 (6.8)	3.1 (0.2)	92.0 (9.9)
	R-TO=60	31	43.7 (4.7)	2.3 (0.1)	100.0 (0.0)
	R-TO=15	13	41.9 (3.5)	5.8 (0.1)	94.0 (1.9)
	R-TO=30	21	49.1 (4.5)	3.8 (0.1)	99.5 (1.1)
	TO-TO=30	15	35.8	0.9	
	1:1				
	R-TO=30	17	44.5 (5.0)	3.2 (0.1)	99.7 (0.7)
	R-TO=60	18	51.0 (3.2)	2.6 (0.1)	100.0 (0.0)
	R-TO=15	13	51.6 (3.0)	5.7 (0.3)	95.3 (2.4)
	R-TO=30	14	44.8 (3.0)	3.8 (0.1)	99.7 (0.7)
	TO-TO=30	17	16.9	0.1	
	1:10				
	R-TO=30	16	32.3 (1.5)	3.4 (0.2)	89.1 (7.6)
	R-TO=15	16	31.4 (8.1)	4.9 (0.3)	45.5 (14.4)
	R-TO=60	15	33.2 (4.4)	2.0 (0.1)	100.0 (0.0)
	R-TO=30	47	23.8 (2.5)	3.4 (0.2)	87.3 (10.4)
	TO-TO=30	24	13.1	0.6	
910	1:5				
	R-TO=30	20	98.0 (20.2)	2.8 (0.7)	45.0 (15.0)
	R-TO=15	14	97.2 (5.2)	5.1 (0.3)	40.5 (4.8)
	R-TO=60	13	82.7 (10.4)	2.0 (0.6)	70.0 (15.8)
	R-TO=30	18	98.8 (12.2)	3.6 (0.5)	62.0 (20.5)
	TO-TO=30	3	165.0	0.0	
	R-TO=30[b]	10			
	1:2				
	R-TO=30[a]	59	89.5 (4.2)	2.4 (0.1)	80.0 (4.0)
	R-TO=15	42	109.3 (8.6)	4.3 (0.5)	62.8 (12.9)
	R-TO=60	15	88.7 (9.0)	1.5 (0.1)	92.0 (5.7)
	R-TO=30	20	76.5 (11.9)	2.6 (0.1)	84.5 (7.4)
	TO-TO=30	10	17.7	0.2	
	1:1				
	R-TO=30	15	55.5 (8.0)	2.1 (0.2)	65.0 (6.8)
	R-TO=15	23	74.2 (10.6)	4.4 (0.1)	70.5 (1.3)
	R-TO=60	31	72.1 (7.3)	1.7 (0.1)	94.0 (1.5)
	R-TO=30	19	59.3 (4.5)	2.2 (0.1)	75.7 (7.3)
	TO-TO=30	12	60.5	0.1	
	1:10				
	R-TO=30	14	65.8 (8.5)	2.6 (0.1)	43.6 (10.0)
	R-TO=15	26	75.3 (8.1)	3.6 (0.3)	17.3 (3.8)
	R-TO=60	12	82.0 (5.9)	1.3 (0.1)	53.3 (13.9)
	R-TO=30	29	69.5 (5.4)	2.5 (0.1)	41.8 (8.1)
	TO-TO=30	46	60.0	0.9	
1046	1:5				
	R-TO=30[a]	13	50.3 (1.1)	4.9 (0.1)	90.0 (3.5)
	R-TO=15	55	38.0 (3.1)	7.4 (0.3)	71.5 (6.8)
	R-TO=60	21	42.5 (0.7)	2.6 (0.0)	90.0 (0.0)
	R-TO=30[b]	12			
	R-TO=30	14	40.1 (1.5)	3.3 (0.3)	86.0 (6.5)
	TO-TO=30	10	14.6	0.0	

Table 1

(*Continued*)

Pigeon	Phase/Condition	Sessions	Resp/min Food Key	Resp/min Post Key	% TO Avoided
	1:2				
	R-TO=30	43	39.6 (2.1)	4.0 (0.2)	89.5 (10.8)
	R-TO=15	12	41.8 (4.1)	6.2 (0.2)	65.5 (4.2)
	R-TO=60	11	46.0 (5.1)	2.4 (0.1)	90.0 (7.9)
	R-TO=30	13	65.5 (5.4)	3.9 (0.3)	81.5 (7.8)
	TO-TO=30	14	38.4	0.1	
	1:1				
	R-TO=30	17	60.8 (3.0)	3.8 (0.1)	87.3 (3.2)
	R-TO=15	12	64.4 (2.5)	6.1 (0.3)	67.8 (5.9)
	R-TO=60	13	47.0 (4.8)	2.4 (0.1)	99.3 (1.5)
	R-TO=30	40	48.9 (2.5)	3.1 (0.2)	89.3 (4.2)
	TO-TO=30	12	66.7	0.3	
	1:10				
	R-TO=30	20	65.1 (1.3)	4.0 (0.1)	63.6 (6.4)
	R-TO=15	14	47.0 (8.7)	2.5 (1.1)	3.6 (3.8)
	R-TO=30	32	54.2 (2.5)	2.8 (0.1)	29.1 (4.1)
	R-TO=15	50	44.9 (15.3)	0.9 (1.2)	0.9 (2.0)
	R-TO=60	24	49.6 (5.1)	1.5 (0.1)	30.0 (13.9)
	R-TO=30	19	70.6 (4.5)	1.8 (0.5)	5.5 (5.0)
	TO-TO=30	47	83.3	0.0	
626	1:5				
	R-TO=30[a]	13	49.3 (10.5)	5.4 (0.7)	96.0 (4.2)
	R-TO=15	28	88.9 (7.6)	8.9 (0.4)	98.0 (3.3)
	R-TO=60	13	77.9 (3.5)	2.7 (0.1)	100.0 (0.0)
	R-TO=30	14	69.5 (8.4)	5.1 (0.1)	96.0 (6.5)
	TO-TO=30[b]	7			
	TO-TO=30	16	103.1	2.5	
	1:2				
	R-TO=30	21	77.6 (7.5)	6.1 (0.7)	100.0 (0.0)
	R-TO=15	13	99.3 (5.9)	9.4 (0.5)	93.8 (7.2)
	R-TO=60	14	102.0 (3.1)	9.6 (0.5)	94.0 (8.2)
	R-TO=30	13	89.8 (6.8)	5.6 (0.3)	98.0 (3.3)
	TO-TO=30	30	60.2	31.6	
	TO-TO=30[c]	49			
	TO-TO=30	10	97.5	7.5	
	1:1				
	R-TO=30	20	103.7 (3.8)	5.7 (0.3)	99.3 (0.9)
	R-TO=15	25	116.4 (8.3)	10.4 (1.1)	98.2 (1.6)
	R-TO=60	29	105.8 (8.5)	3.0 (0.3)	100.0 (0.0)
	R-TO=30	40	101.9 (5.8)	3.8 (0.4)	99.3 (0.9)
	TO-TO=30	63	113.6	4.7	

[a] = changeover delay in place from this condition forward;
[b] = error, data not presented;
[c] = extended changeover delay conditions, collapsed into a single cell.

present study employed more subjects and explored a much wider range of conditions than did the Thomas study. Postponement responding was systematically related to the contingencies: Responding occurred consistently under postponement conditions, in which effective responding was permitted, and at low levels under extinction conditions, when it was not. The only exceptions occurred for Pigeon 626 in the final two sets of conditions in which responding persisted under extinction conditions. Although this finding is somewhat anomalous in the context of the present results, which were remarkably similar within and across subjects, the persistence of responding in extinction on TO-postponement contingencies is not unprecedented. Pietras and Hackenberg (2000) found similar response persistence even after prolonged exposure to extinction. Both there and in the present study, subjects had extensive experience with TO-postponement contingencies prior to the development of such persistence.
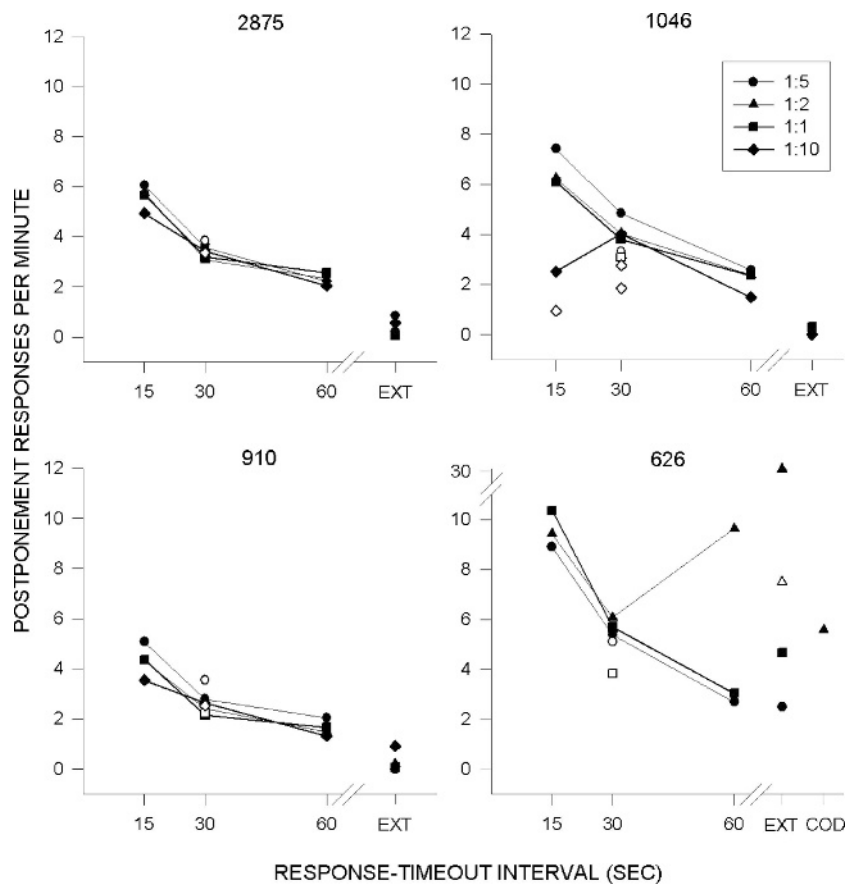
Fig. 1.   Mean rate of postponement responses for each pigeon over the final five sessions of each R–TO condition, and last session of EXT conditions. Symbols indicate RTO:TO duration and appear in the legend in the order of exposure. Unfilled points represent replication conditions.

Postponement response rates varied inversely with R–TO interval for all 4 pigeons across all R–TO:TO ratios studied, providing strong evidence of temporal control by the contingencies. We also analyzed postponement response rates within each R–TO value in relation to TO duration (comparing data from like R–TO values across different phases), but these functions were much less orderly than those obtained with R–TO as the parameter.

Postponement responding also came under strong discriminative control by the time-correlated stimulus changes, gravitating toward stimuli positioned later in the cycle (S2 and S3). When viewed in relation to food-key responding (Figure 4 and Appendix), these data reveal a consistent pattern: food-key responding in S1 and postponement responding in S2 and S3.

The stimulus occasioning the most frequent postponement responding varied across subjects. For Pigeons 1046 and 626, modal response frequency was occasioned by S2, the middle stimulus in the cycle. Even when corrected for opportunity (Figure 3), strong control by S2 is evident. Although there was some tendency for both pigeons to respond in S3 when it was available, the relative frequency data (Appendix A) show that S3 was rarely present. Responses occurred at sufficiently high levels in S2 to preclude consistent contact with S3. The temporal distributions were roughly invariant even as the R–TO interval underwent significant changes (Figure 3). This suggests that postponement responding was under strong stimulus control by the time-correlated stimuli.

A somewhat different temporal response pattern emerged for Pigeons 910 and 2875.
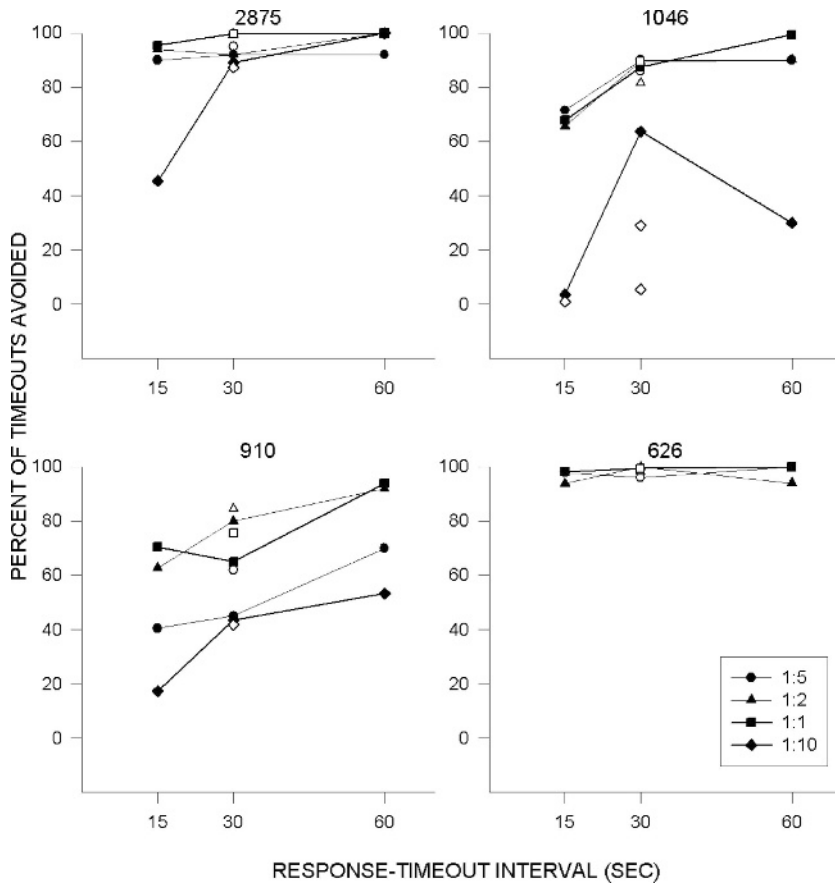
Fig. 2. Mean percent of timeouts avoided for each pigeon over the final five sessions of each condition. Symbols indicate RTO:TO duration and appear in the legend in the order of exposure. Unfilled points represent replication conditions.

For Pigeon 910, responding occurred most frequently in S3, whereas for 2875, the stimulus occasioning the modal response frequency varied across conditions: S2 in long R–TO conditions, S3 in short R–TO conditions, and mixed S2 and S3 in intermediate R–TO conditions. The mixed control was evident not only in the number of conditions in which S2 or S3 occasioned higher responding, but also in the more variable temporal distributions.

Data from these conditions suggest that some degree of variability with respect to the conditions under which postponement responses occur may facilitate sensitivity to changes in R–TO contingencies. In the present experiment, such control by the contingencies was confounded with exteroceptive control by the time-correlated stimulus changes. The purpose of

Experiment 2 was to investigate further the stimulus functions of the time-correlated stimuli in discriminated TO-avoidance contingencies.

EXPERIMENT 2

The data from Experiment 1 indicate that postponement responses usually occurred toward the end of the R–TO interval, in the presence of stimuli more proximal to TO. This suggests a discriminative role for the added stimuli, delineating periods during which responding is maximally efficient. To more clearly assess the discriminative functions of the added stimuli, however, it is necessary to selectively manipulate the contingencies in the presence of the preaversive stimuli.

Such manipulations were the focus of a classic pair of experiments by Sidman and Boren
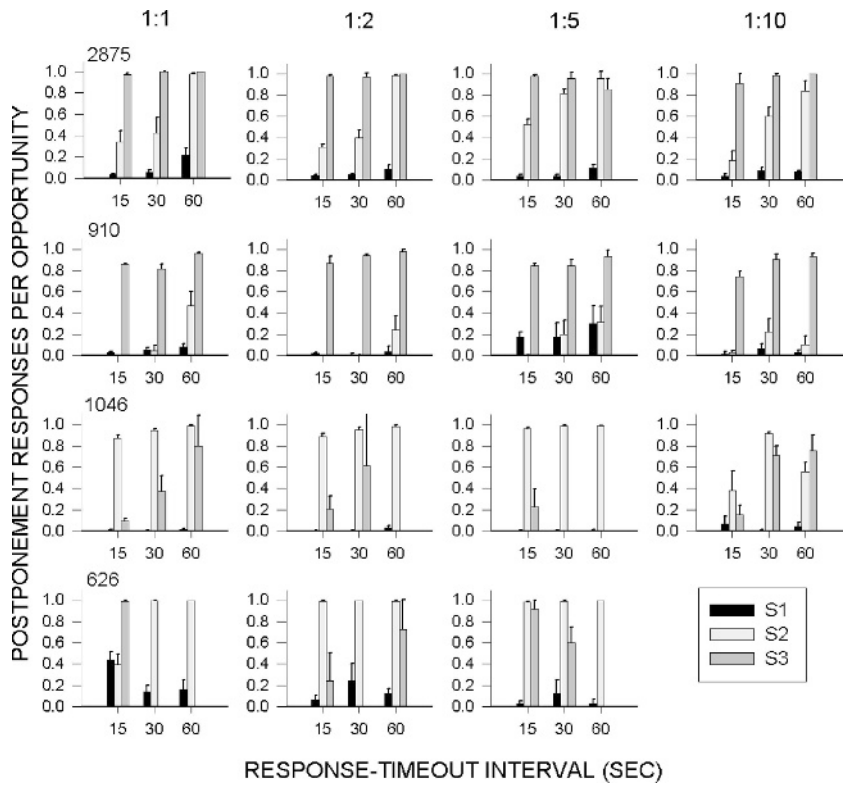
Fig. 3. Mean conditional probability of a postponement response in the presence of the time-correlated stimuli for each pigeon over the final five sessions of each condition. The data are arrayed vertically by phase (RTO:TO duration) and horizontally by subject.

(1957a, b) in the shock-avoidance realm. In one of these (Sidman & Boren, 1957a), 7 rats were exposed to procedures in which a preshock (warning) stimulus was superimposed on a free-operant shock-postponement contingency. For 3 rats, responses made in the presence of the warning stimulus terminated the stimulus and postponed the upcoming shock. These rats tended to wait until the warning stimulus was present before responding, both terminating the stimulus and avoiding the shock. For the other 4 rats, responses during the warning stimulus were ineffective. Unlike their counterparts in the first group, these rats tended to respond prior to the warning stimulus, postponing both the shock and the warning stimulus.

In a related experiment (Sidman & Boren, 1957b), responses made during a 15 s response–light (R–L) interval (during which no warning stimulus was present) postponed the onset of the light and restarted the R–L interval. If no response occurred during the R–L interval, then a warning stimulus was illuminated and a 5 s response–shock (R–S) interval was initiated. Responses made during the R–S interval reset the interval, postponing shock for an additional 5 s. Thus, responses were effective both in the presence and absence of the warning stimulus, but the contingencies differed: R–S 20 s in dark and R–S 5 s in light. The rats tended to respond prior to the stimulus, preventing both the stimulus and the shock. Taken together with the results of their other experiment described above, Sidman and Boren's findings suggest a clear discriminative role for the warning stimuli, signaling periods of maximally efficient behavior.

The present experiment is modeled after some of the conditions in Sidman and Boren's (1957a, b) studies, but with TO substituted for shock. We selectively manipulated the contingencies in the presence of the time-correlated
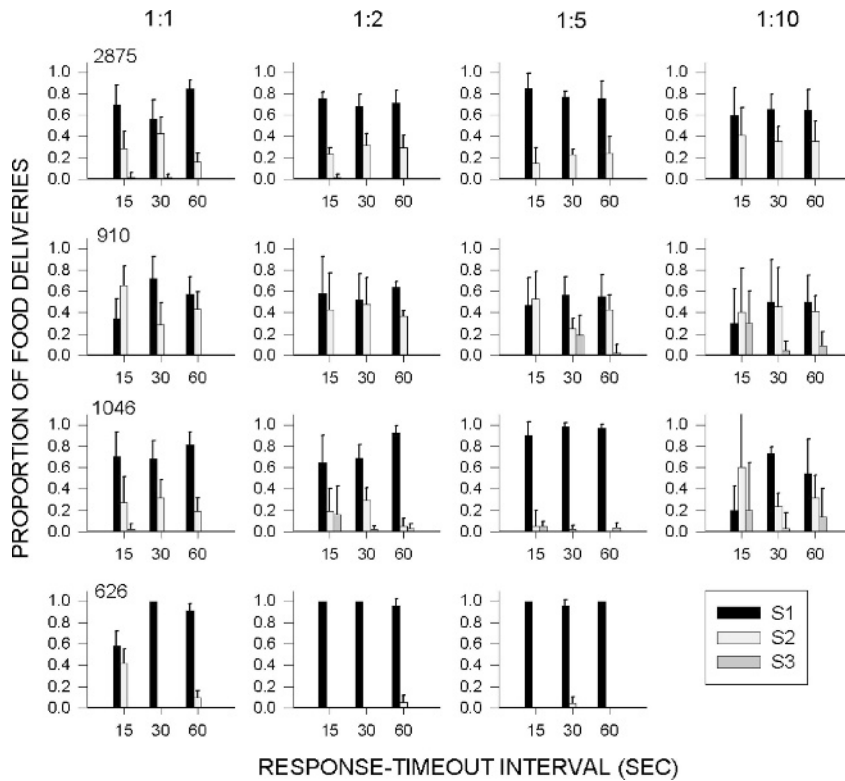
Fig. 4. Mean proportion of food deliveries in the presence of the time-correlated stimuli for each pigeon over the final five sessions of each condition. The data are arrayed vertically by phase (RTO:TO duration) and horizontally by subject.

stimuli, comparing TO-postponement responding under standard (baseline) conditions to that under conditions in which stimuli signaled differentially effective contingencies. In some conditions, responses made in the presence of S1 and S2 reset the R–TO as in Experiment 1, but responses made in the presence of S3 were ineffective, such that S3 signaled an unavoidable TO. Additional conditions were arranged in which stimuli signaled different R–TO contingencies: responses in the presence of some of the time-correlated stimuli reset the R–TO as in Experiment 1, but responses made in the presence of other stimuli reset the R–TO only to the beginning of the operative segment of the R–TO (i.e., required a higher response rate and produced no stimulus change). In still other conditions, standard TO-postponement responding with added stimuli (discriminated avoidance) was compared to that in the absence of added stimuli (nondiscriminated avoidance).

METHOD

Subjects and Apparatus

The pigeons that completed Experiment 1 (910, 1046, 2875) served as subjects. All other conditions of housing and testing were identical to Experiment 1.

Procedure

Experiment 2 began without a break upon the completion of Experiment 1. The schedule of food reinforcement, session duration, and order of presentation of the time-correlated stimuli were identical to Experiment 1. Baseline conditions in the present experiment were identical to the R–TO:TO = 1:2 condition from Experiment 1, in which the R–TO was 30 s and the TO duration was 60 s. These parameters were held constant throughout Experiment 2. The order of conditions and number of sessions per condition are shown in Table 2.

The main experimental manipulations can be separated into three categories. The first

Table 2

Order of conditions and number of sessions for each pigeon in Experiment 2. Condition labels are abbreviated as follows: Baseline (BL), Partial Extinction (PE), Partial Postponement (PP), Nondiscriminated Avoidance (ND), and Nondiscriminated Avoidance with alternate time-correlated stimuli (ND ALT). See text for other details.

2875		910		1046	
Condition	Sessions	Condition	Sessions	Condition	Sessions
BL	22	BL	17	BL	20
PE3	37	PE3	46	PE3	20
PP3	14	BL	21	BL	32
PP2+3	17	PP3	25	PP3	23
BL	18	PP2+3	37	PP2+3	45
PP2	29	PP3	21	BL	51
ND	13	PP3[a]	19	ND	13
BL	8	PP3	20	BL	24
ND	13	PP2	26	ND	19
BL	19	PE1+2	25		
ND ALT	24	PP3	14		
		PP3[a]	13		
		BL	45		
		ND	14		
		BL	24		
		ND	27		

[a] = Duration of S1 was 40 s during these conditions.

category of conditions was termed *Partial Extinction*, in which postponement responses were rendered ineffective in the presence of some but not all of the time-correlated (warning) stimuli. For example, in Partial Extinction 3, postponement responses in the presence of S1 or S2 had their usual effects (resetting the R–TO interval and reinstating S1), but responses in the presence of S3 had no effect: Once S3 was presented, the TO was unavoidable. This condition was conducted immediately after the baseline condition for all subjects.

The second category of conditions was termed *Partial Postponement*, in which postponement responses in the presence of selected stimuli reset the R–TO, not to the beginning of the entire R–TO interval (30 s), but to the beginning of the active segment. For example, in Partial Postponement 2, postponement responses made in the presence of either S1 or S3 had their usual effects (reset the R–TO interval to 30 s and reinstated S1), but responses in the presence of S2 reset the R–TO only to 20 s (the beginning of S2), with no stimulus change on the key. In the conditions labeled Partial Postponement 2+3, postponement responses in the presence of any of the three stimuli reset the R–TO to the beginning of the active segment, with no

stimulus changes. (Note that Pigeon 1046 did not experience the Partial Postponement 2 condition.) Pigeon 910 also experienced two exposures to a modified Partial Postponement 3 condition in which S1 was presented for 40 s (in the absence of a postponement response) instead of the usual 10 s. These conditions did not produce systematic changes in the dependent variables and, therefore, were excluded from the present analysis, as were additional exposures to the Partial Postponement 3 condition that served primarily as comparisons for these conditions.

The third category of conditions was termed *Nondiscriminated Avoidance*, in which only one stimulus was presented for the entire R–TO interval. These conditions were conducted using the S1 stimulus from the previous discriminated avoidance procedures, except in the final condition for Pigeon 2875 (ND ALT), in which S3 was used. Two Nondiscriminated Avoidance conditions were conducted per subject, alternating with baseline conditions.

RESULTS

Appendix B shows time allocation, responses, and reinforcers in the presence of each of the time-correlated stimuli, along with the number of TOs per condition for each

Fig. 5. Mean conditional probability of a postponement response in the presence of the time-correlated stimuli for each pigeon over the final five sessions of baseline (BL), Partial Extinction (PE), and Partial Postponement (PP) conditions in Experiment 2. See text for other details.

pigeon in Experiment 2. Figures 5 and 6 show the conditional probabilities of a postponement response for each pigeon in the presence of the three time-correlated stimuli across the final five sessions in each condition. As in Figure 3, these response distributions are corrected for opportunity. For ease of exposition, data from Partial Extinction and Partial Postponement conditions are shown in Figure 5, and those from Nondiscriminated Avoidance conditions are shown in Figure 6, along with relevant baseline conditions for comparison. Data in both figures are shown in the order in which the conditions were conducted.

Considering first the baseline data, conditional response probabilities were similar to those under identical conditions (R–TO:TO = 1:2) from Experiment 1 (Figure 3). The

temporal distributions were generally graded in relation to TO proximity, even for Pigeon 1046 whose high levels of S2 responding in Experiment 1 precluded effective contact with S3. Across subjects, response probability was highest in S3 in 11 of 12 baseline conditions.

When contingencies were selectively manipulated in the presence of S3—either made ineffective (Partial Extinction 3) or correlated with a more stringent response requirement (Partial Postponement 3)—distributions shifted to the left, decreasing in the presence of S3 and increasing in the presence of stimuli earlier in the cycle. Pooled across subjects and Partial Extinction 3 and Partial Postponement 3 conditions, distributions shifted leftward relative to the nearest baseline condition in six of seven conditions. Similarly, in the two Partial Post-
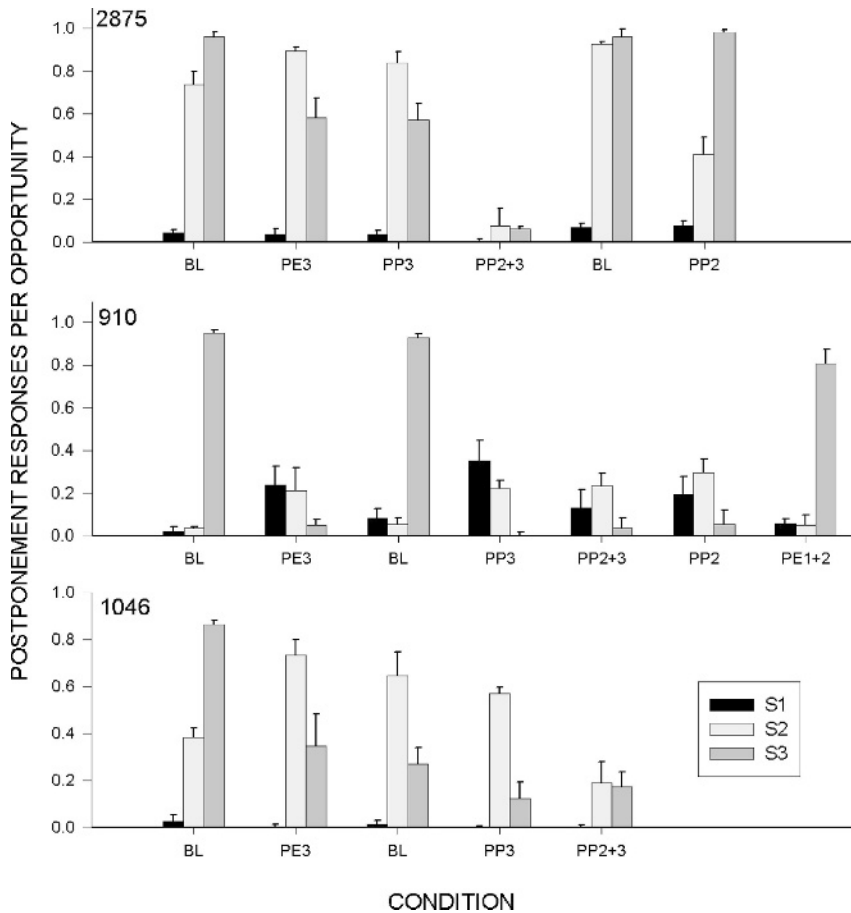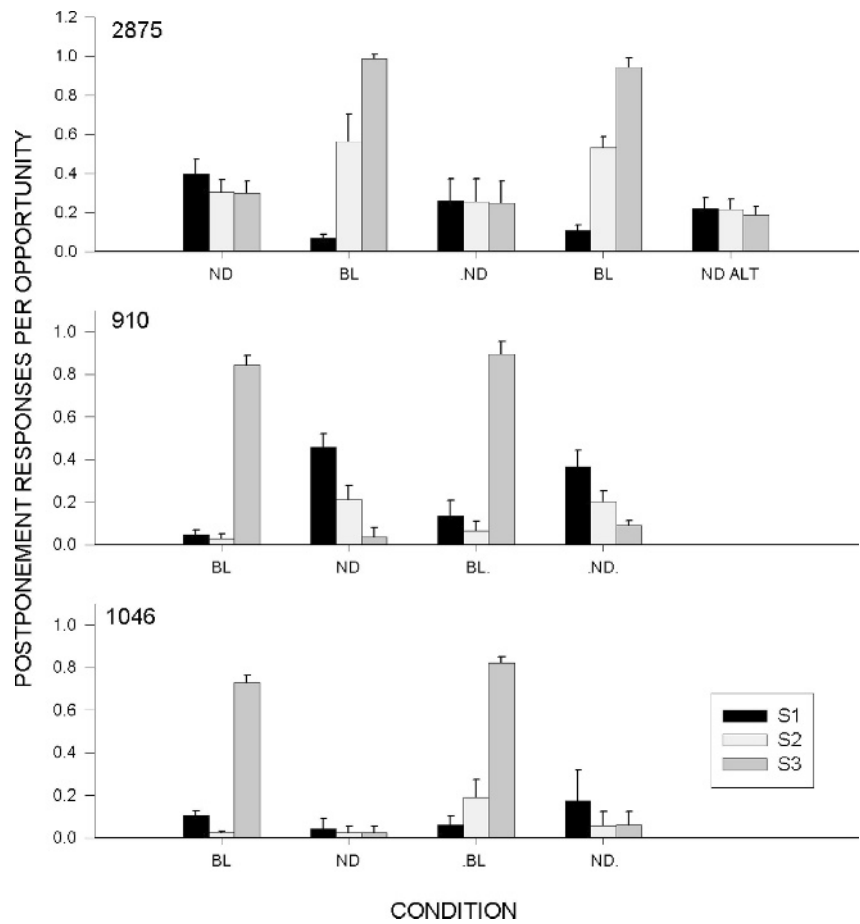
Fig. 6.   Mean conditional probability of a postponement response in the presence of the time-correlated stimuli for each pigeon over the final five sessions of baseline (BL) and Nondiscriminated Avoidance (ND) conditions.

ponement 2 conditions, in which the R–TO contingencies were selectively manipulated in the presence of the S2 stimulus, there was some tendency for response probability to shift away from S2 (toward S3 for Pigeon 2875 and toward S1 for 910), though the effects were less robust than those seen in the Partial Postponement 3 conditions. Because for Pigeon 910 response probability remained highest in S2 in this condition, the subsequent condition rendered ineffective responses in S1 and S2 (Partial Extinction 1+2). This condition produced an appropriate rightward shift in the distribution. The Partial Postponement 2+3 condition, in which the R–TO contingencies were made more stringent in both S2 (R–TO=20) and S3 (R–TO=10), sustained weak and inconsistent postponement responding in all 3 pigeons.

Figure 6 shows postponement responding with and without added stimuli. Data from the baseline conditions are portrayed as in Figure 5; those from the Nondiscriminated Avoidance conditions are binned in similar fashion, but because there were no stimulus changes, these data reflect only the temporal distribution of responding. When the time-correlated stimuli were removed (Nondiscriminated Avoidance conditions), postponement responses were much less probable than during the conditions with added stimuli, but recovered to baseline levels when the stimuli were reinstated. A return to Nondiscriminated Avoidance conditions again reduced postponement responding, demonstrating clear and consistent effects of the added stimuli. Removing the stimuli also altered the temporal distribution

of postponement responding. For Pigeon 910, the distribution reversed such that responses were most likely in the initial one-third of the interval. For Pigeons 2875 and 1046, the distribution flattened, such that responses were equally likely throughout the R–TO interval. Changing the stimulus in the presence of which the Nondiscriminated Avoidance condition was conducted from S1 to S3 for Pigeon 2875 (ND ALT) had no effect on the level or distribution of postponement responding.

<div align="center">DISCUSSION</div>

The results of Experiment 2 suggest that the time-correlated stimuli in a TO-avoidance procedure serve important discriminative functions. There are several lines of evidence bearing on this conclusion. To begin with, when the added stimuli were removed in the latter set of conditions, postponement responding decreased appreciably. Although postponement responding was maintained without added stimuli for 2 of 3 pigeons, the rate of such behavior was less than under discriminated avoidance conditions (Figure 6 and Appendix B).

Even stronger evidence of discriminative control comes from the temporal distribution data—the responses in the presence of the time-correlated stimuli. Under baseline conditions, the response distributions were strongly skewed in favor of S3—the stimulus proximal to TO. In the Partial Extinction 3 conditions, in which responses in the presence of S3 were rendered ineffective in postponing the TO, there were some differences with respect to the conditional probability of postponement responses occurring in the presence of S3. As shown in Figure 5, Pigeons 910 and 1046 rarely responded during S3. This result is similar to the findings of Sidman and Boren (1957b) who reported that rats would wait through an R–S interval of 5 s and experience a shock when doing so produced a longer shock-free interval. In contrast, Pigeon 2875 often pecked the postponement key in the presence of S3 in the Partial Extinction 3 condition. However, for all pigeons the distribution of behavior shifted from that occurring primarily in the presence of S3 (baseline) to that occurring prior to S3. Similarly, in Partial Postponement 2 and Partial Postponement 3 conditions, in which R–TO contingencies were selectively altered in the presence of S2 and

S3, respectively, response distributions tended to shift in accord with the contingencies, occurring in the presence of stimuli correlated with less stringent R–TO requirements, even when such changes brought behavior closer to TO (as for Pigeon 2875 under PP2 conditions). Together, these results follow from a discriminative stimulus view of the added stimuli. When S3 signaled a period of effective responding, most responses occurred in the presence of that stimulus. Conversely, when the stimulus signaled extinction or a more stringent response requirement, responses shifted to an earlier part of the cycle, where they were more effective. Thus, responding came to occur in the presence of stimuli delineating periods during which it was effective.

<div align="center">GENERAL DISCUSSION</div>

The present study explored TO postponement across a wide range of contingencies and in relation to correlated stimulus changes. Behavior came under systematic control of TO-postponement contingencies, occurring consistently under postponement conditions and at low levels under extinction conditions. Postponement response rates varied inversely with R–TO interval, a function that was generally consistent across subjects and R–TO:TO ratios. The inverse relationship between response rates and R–TO interval has been reported previously with pigeons (Galbicka & Branch, 1983; Thomas, 1965), rats (D'Andrea, 1971; van Haaren & Zarcone, 1994), and chimpanzees (Ferster, 1958). Similar functions have been reported with shock as the aversive stimulus: Response rates vary inversely with the duration of the R–S interval (Clark & Hull, 1966; Sidman, 1953). This general comparability in the functions obtaining with TO and shock suggests that the stimuli share functional properties.

The present study also varied relative TO duration (the ratio of R–TO:TO), but it did not produce consistent differences in avoidance responding. One measure that showed some sensitivity to this variable was avoidance proficiency, as assessed by the percent of TOs avoided (Figure 2). By this measure, there was some decrement in performance at the most extreme ratio (1:10) for 3 of 3 pigeons, particularly at the lower R–TO values. These

effects of relative TO duration are broadly consistent with the results of a similar manipulation by Thomas (1965, Experiment 4) in which TO duration was evaluated in the context of a discriminated TO-postponement procedure with a single R–TO value of 60 s. Although Thomas did not report avoidance proficiency, he found a curvilinear relationship between response rate and TO duration, such that moderate TO durations (120 s) produced higher rates than did shorter (30 s) or longer (900 s) TO durations. When converted to relative TO durations of 2:1, 1:2, and 1:15, these effects are generally comparable to the effects reported above, albeit for avoidance response rates rather than avoidance proficiency per se. Like Thomas, we found that responding was lowest at the highest relative TO duration. The present experiment did not explore lower relative TO durations (i.e., where R–TO exceeds TO duration). Perhaps if we had, we too would have seen the curvilinear relation reported by Thomas.

Other studies examining relative TO duration have yielded mixed results. Using a conjoint TO-deletion procedure with pigeons, in which responses to a single key both produced food according to a random-interval schedule and postponed TO according to a fixed-ratio schedule, Hackenberg (1992) found that a 1:5 TI:TO ratio produced clearer and more systematic effects than a 2:1 ratio, though the effects were confounded with order effects; all pigeons experienced the 1:5 ratio after the 2:1 ratio. Clearly, in light of the relatively meager empirical base, additional research is needed to clarify the relationship between avoidance behavior and TO duration.

The same might be said of the relationship between avoidance and shock intensity, considered the functional equivalent to TO duration in comparisons of TO and shock. Using a free-operant shock-postponement schedule with pigeons, Klein and Rilling (1972) found that response rates increased with shock intensity across a range of low to moderate intensities, before leveling off at larger intensities. Similar functions have been reported with rats as subjects (Boren, Sidman, & Herrnstein, 1959; Iso, 1986; Reiss, 1970), but the effective intensity range with either species is rather small. At higher intensities, unconditioned responses to shock become more prevalent, responses that may compete with avoidance. Similarly, longer TO durations may result in a general suppression of behavior. Thomas (1965) reported that under the longest TO duration (900 s), responding on both the avoidance key and the food key was suppressed.

Responding was usually quite proficient, as most scheduled TOs were avoided. This, too, is consistent with results in the shock-avoidance realm where experienced subjects avoid a high percentage of scheduled shocks. One common effect reported with shock-avoidance but absent in the present study is the transient early session decrement in responding—the so-called ''warm-up effect'' (Hineline, 1978). We examined within-session responding but found no evidence of changes in TO rate across the session.

The present results also bear on the role of time-correlated (warning) stimuli on TO-avoidance performance. Under Nondiscriminated Avoidance conditions (Experiment 2), avoidance performance diminished substantially relative to conditions with added stimuli. These findings are consistent with the results of Thomas (1965). Following a history of discriminated TO avoidance, Thomas' pigeons stopped responding when the time-correlated stimulus changes were discontinued (nondiscriminated avoidance). He attributed the weak responding under Nondiscriminated Avoidance conditions to the absence of immediate stimulus changes following a response. That is, an effective response under discriminated avoidance conditions both reset the R–TO interval and reinstated S1 (the stimulus correlated with maximum temporal distance from TO), but under Nondiscriminated Avoidance conditions, a response only reset the R–TO interval. Perhaps these immediate stimulus changes were critical in the present study, as well. When such stimulus changes were lacking, as in several conditions in Experiment 2, avoidance rates decreased appreciably. This was true not only of the Nondiscriminated Avoidance conditions but of the Partial Postponement conditions as well. Recall that in these conditions, responses remained effective in postponing TO but they did not reinstate S1. The decrement in avoidance performance seen for some pigeons in these conditions suggests the importance of contingent stimulus change in discriminated TO–avoidance.

Such response-produced stimulus changes also entered into relations with food during TI conditions. The S1 stimulus signaled not only the greatest temporal distance from TO but also the highest rate of food reinforcement. Although the VI food schedule operated continuously across the R–TO cycle, the majority of the food was earned in S1, establishing the transition to S1 as conditioned positive reinforcement. The high incidence of responding in S2 or S3 likely reflects the joint influence of negative reinforcement via the TO-postponement contingency and positive reinforcement via the transition to a food-correlated stimulus.

Although we were able to sustain avoidance at low levels in 2 of 3 pigeons, the general weakness of nondiscriminated TO avoidance appears to be at variance with the robust effects of nondiscriminated shock avoidance (Baron, 1991; Hineline, 1977). In comparing TO and shock avoidance, however, it is important to note a key procedural difference. Standard shock-postponement procedures involve but a single contingency that specifies the temporal relations between behavior and shock. Standard TO-avoidance procedures, however, usually involve concurrent contingencies—a schedule of positive reinforcement that specifies relations between behavior and food during TI conditions and a schedule of negative reinforcement that specifies relations between behavior and TO. Responding in such concurrent food–avoidance arrangements reflects the joint influence of TI and TO contingencies.

The concurrent arrangement of food and TO-postponement contingencies produced consistent temporal patterning, partitioned in relation to the time-correlated stimuli: food-key responses early in the cycle (S1), followed by a single response in the presence of S2 or S3 that reset the R–TO interval and reinstated S1. When the stimuli signaled identical R–TO contingencies (Experiment 1 and baseline conditions of Experiment 2), responses occurred toward the end of the R–TO interval, in the presence of stimuli proximal to TO. These data on the temporal distribution of responding in the presence of preaversive stimuli are broadly consistent with those reported previously both with TO (Thomas, 1965) and with shock (Field & Boren, 1963; Sidman, 1955; Sidman & Boren, 1957a, b; Ulrich, Holz, & Azrin, 1964).

The added stimuli appear to serve mainly discriminative functions, delineating periods of maximally effective responding (Hineline, 1981). Although this does not rule out other functions as well (e.g., conditioned aversive functions based on embedded S–S pairings), the balance of evidence supports a view based on the discriminative functions of the stimuli. The most compelling evidence comes from the conditions in Experiment 2 when R–TO contingencies were selectively altered in the presence of the added stimuli. Responses usually shifted to stimuli in the presence of which more effective operant contingencies prevailed. On the whole, the data follow quite directly from a consideration of the discriminative functions of the stimuli differentially correlated with operant contingencies, paralleling discriminative functions of added stimuli in shock-avoidance procedures (Hineline, 1977, 1981, 1984).

On a more applied note, the present results have implications for behavioral interventions employing TO from reinforcement—among the oldest and most successful procedures in applied behavior analysis. Outside the laboratory, TOs are often avoidable (e.g., by engaging in behavior other than some response targeted for punishment) and are correlated with stimuli signaling differential consequences (e.g., a caregiver arranging the contingencies). Suppose that a caregiver provides warnings prior to administering a TO (e.g., ''You are headed for a TO''), and in one case the TOs are avoidable but in another case they are not. The warnings would come to serve somewhat different functions in the two situations, delineating periods of differentially effective behavior, as did the pre-TO stimuli in the present study. The child may be more likely to wait until the warning before making the avoidance response in the first case (when the warning signals an effective avoidance contingency) than in the second case (when the warning signals impending TO). This follows directly from the present findings in which behavior came under discriminative control of stimuli differentially correlated with maximal response efficacy. Although not designed in relation to applied objectives, the present study may serve as a laboratory model of behavior in a TO context, permitting a much needed analysis of the behavioral mechanisms responsible for this commonly

used but poorly understood set of contingencies (Hackenberg & DeFulio, in press).

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APPENDIX A

Number of food-key responses, food deliveries, postponement-key responses, timeouts, and amount of time spent in timein as a function of stimulus for each pigeon in Experiment 1. Data show means from the last five sessions of each condition.

Subject	Phase/ Condition	Timein			Food Responses			Food Deliveries			Postponement Responses			Timeouts
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	
2875	1:5													
	R-TO=30	1934.7	1278.8	99.6	2194.0	375.8	2.0	10.8	3.2	0.0	7.6	155.6	34.2	1.6
	R-TO=15	1619.7	1415.0	221.1	1644.6	333.4	5.0	11.4	2.0	0.0	12.6	166.4	149.6	4
	R-TO=60	2277.2	1031.8	34.7	2316.6	225.6	3.4	9.4	3.0	0.0	14.0	104.6	4.6	0.8
	R-TO=30	1843.6	1417.0	126.3	2089.0	331.2	1.4	9.4	3.2	0.0	14.8	127.4	53.8	1
	TO-TO=30	200.0	200.0	200.0	57.6	8.2	69.8	1.4	0.0	1.4	3.0	0.6	0.4	20
	1:2													
	R-TO=30	1681.8	1470.9	204.8	1779.2	574.0	10.6	8.2	3.8	0.0	9.0	65.6	97.4	3.2
	R-TO=60	2527.7	991.7	4.5	2157.4	408.4	0.2	10.8	4.4	0.0	14.0	119.6	2.4	0
	R-TO=15	1601.0	1459.5	329.0	1908.4	450.2	9.4	10.4	3.2	0.2	14.4	97.4	213.4	4.8
	R-TO=30	2136.7	1330.7	46.6	2475.6	400.0	1.2	10.8	4.0	0.0	10.6	182.2	29.4	0.2
	TO-TO=30	400.0	400.0	400.0	133.6	137.2	306.4	1.8	1.2	2.2	0.2	6.2	17.4	40
	1:1													
	R-TO=30	1803.8	1530.5	186.7	1899.2	709.0	4.8	8.2	6.2	0.2	10.4	74.8	101.4	0.2
	R-TO=60	2732.6	788.4	4.5	2620.0	378.4	0.2	12.6	2.4	0.0	32.8	114.8	2.6	0
	R-TO=15	1629.4	1443.0	377.5	2383.4	576.4	9.6	9.2	3.8	0.2	11.0	109.0	206.0	5.6
	R-TO=30	2172.1	1274.3	81.6	2148.0	481.8	2.0	9.8	3.4	0.0	26.4	153.4	46.0	0.2
	TO-TO=30	600.0	600.0	600.0	96.6	62.4	206.8	0.2	0.6	1.0	0.0	2.8	0.2	60
	1:10													
	R-TO=30	1758.4	1250.0	171.5	1343.4	365.8	3.4	7.8	4.2	0.0	15.6	100.0	66.2	1.2
	R-TO=15	815.2	756.7	284.2	764.6	219.8	23.2	2.6	1.8	0.0	6.4	29.6	118.6	12
	R-TO=60	2281.9	1211.2	38.8	1537.0	415.8	0.6	8.8	4.8	0.0	10.0	91.8	18.4	0
	R-TO=30	1775.3	1262.6	127.8	1050.6	210.8	1.4	8.0	3.6	0.0	3.4	122.2	52.0	1.4
	TO-TO=30	110.0	110.0	110.0	17.2	22.4	41.6	0.4	0.0	0.2	2.6	3.4	2.4	11
910	1:5													
	R-TO=30	946.2	778.2	243.6	1584.4	1248.8	282.4	3.6	1.6	1.2	18.8	17.0	58.8	11
	R-TO=15	759.4	743.4	339.4	1214.8	1644.6	127.4	1.6	1.8	0.0	31.4	0.2	124.4	23.8
	R-TO=60	1403.2	1092.0	211.3	2123.0	1410.0	134.8	4.4	3.4	0.2	28.0	20.4	41.8	3
	R-TO=30	1263.2	929.9	267.6	2306.6	1580.8	99.6	4.6	2.0	0.2	44.8	28.2	73.4	7.6
	TO-TO=30	200.0	200.0	200.0	418.7	503.7	995.3	0.7	0.0	1.7	0.0	0.0	33.0	20
	1:2													
	R-TO=30	1322.9	1308.7	459.5	2688.6	1849.6	75.6	5.0	4.6	0.0	1.2	0.4	122.6	8
	R-TO=15	1109.2	1095.5	485.8	2591.2	2235.8	99.0	3.8	2.8	0.0	5.2	0.0	189.6	29.8
	R-TO=60	1671.1	1445.1	278.7	3341.4	1665.6	24.8	5.2	3.0	0.0	3.4	20.2	60.8	1.6
	R-TO=30	1424.4	1404.0	384.4	2737.4	1341.4	28.0	6.0	2.4	0.2	4.8	3.0	132.2	6.2
	TO-TO=30	400.0	400.0	400.0	224.4	193.0	37.4	1.0	0.0	0.0	0.0	0.0	5.0	40
	1:1													
	R-TO=30	1209.4	1174.2	564.4	1744.2	965.0	21.6	6.6	2.6	0.0	6.6	5.4	93.4	21
	R-TO=15	1266.6	1251.9	538.6	1914.8	1813.0	52.4	2.0	3.8	0.0	7.0	0.0	215.0	35.4
	R-TO=60	1835.7	1410.5	215.2	2675.4	1469.8	10.8	5.8	4.4	0.0	7.6	42.4	45.8	1.8
	R-TO=30	1300.9	1270.1	576.8	1928.8	1141.6	47.2	3.2	3.4	0.2	2.4	6.4	108.0	14.6
	TO-TO=30	600.0	600.0	600.0	507.2	490.2	437.2	0.0	1.0	0.0	1.2	0.8	2.4	60
	1:10													
	R-TO=30	830.9	696.3	295.3	1173.0	796.0	54.8	2.2	2.0	0.2	5.8	17.4	56.4	6.2
	R-TO=15	361.2	352.7	196.7	517.4	525.0	90.4	0.6	0.8	0.6	1.2	2.0	51.2	18.2
	R-TO=60	963.8	930.8	233.8	1492.2	1335.4	74.4	3.4	2.8	0.6	1.6	5.0	40.0	2.8
	R-TO=30	772.8	713.6	241.9	1075.8	891.2	39.2	2.6	2.6	0.0	3.2	9.4	60.0	6.4
	TO-TO=30	110.0	110.0	110.0	45.4	198.4	197.2	0.0	0.8	0.8	5.6	2.4	3.2	11

APPENDIX A
(*Continued*)

Subject	Phase/Condition	Timein			Food Responses			Food Deliveries			Postponement Responses			Timeouts
1046	1:5													
	R-TO=30	2675.4	571.5	20.0	2628.8	87.2	25.2	10.8	0.2	0.0	0.6	263.4	0.0	2
	R-TO=15	1754.3	906.0	59.5	1572.4	44.8	100.8	7.6	0.4	0.4	0.8	332.0	3.4	11.4
	R-TO=60	2816.7	430.2	20.0	2267.6	14.6	30.8	10.6	0.0	0.4	1.2	138.6	0.0	1
	R-TO=30	1739.5	1270.9	152.0	1539.0	563.0	13.2	3.2	2.6	0.0	7.8	100.6	67.2	2.8
	TO-TO=30	200.0	200.0	200.0	18.6	70.8	91.8	0.0	0.0	0.4	0.0	0.6	6.4	20
	1:2													
	R-TO=30	2289.9	962.2	65.2	1788.8	338.4	66.0	7.0	3.0	0.2	0.6	216.0	6.8	4.2
	R-TO=15	1589.2	1018.6	145.4	1449.8	263.2	203.2	4.0	1.2	1.0	0.8	278.2	7.2	27.6
	R-TO=60	2654.1	642.7	40.3	2411.8	107.8	39.4	7.0	0.4	0.2	3.4	128.2	0.0	2
	R-TO=30	2108.9	946.6	81.7	2839.2	470.2	104.2	6.2	2.2	0.2	1.2	199.6	1.8	7.4
	TO-TO=30	400.0	400.0	400.0	349.2	425.4	267.2	1.6	0.4	0.4	0.0	0.0	44.4	40
	1:1													
	R-TO=30	2207.3	1049.8	93.3	2933.2	375.6	86.4	5.2	2.4	0.0	0.8	206.8	4.6	7.6
	R-TO=15	1726.7	1073.0	194.5	2541.2	386.8	289.0	6.2	2.4	0.2	2.2	298.0	4.2	38.6
	R-TO=60	2798.0	756.6	11.1	2466.8	318.0	7.6	6.0	1.4	0.0	2.2	137.4	0.8	0.2
	R-TO=30	1804.8	1390.4	189.3	1793.6	901.4	63.8	4.8	3.0	0.0	2.0	93.8	78.0	6.4
	TO-TO=30	600.0	600.0	600.0	491.6	633.0	668.6	1.4	1.6	1.8	0.0	3.0	23.6	60
	1:10													
	R-TO=30	1652.2	675.7	63.2	2161.0	381.2	56.4	5.0	1.6	0.2	1.2	149.0	10.0	4
	R-TO=15	210.7	167.2	114.8	133.0	129.2	131.2	0.2	0.6	0.2	2.8	15.4	3.8	21.2
	R-TO=30	668.5	468.4	159.9	668.2	401.2	101.6	3.2	1.6	0.2	1.8	31.2	26.8	7.8
	R-TO=15	140.3	119.9	110.4	65.6	39.4	175.4	0.6	0.0	0.0	0.8	5.2	0.6	21.8
	R-TO=60	800.5	500.3	160.7	640.8	432.2	115.8	2.4	1.4	0.6	1.8	21.8	13.0	4.2
	R-TO=30	275.6	181.5	110.4	291.2	222.0	156.2	0.8	0.2	0.6	1.2	14.0	2.6	10.4
	TO-TO=30	110.0	110.0	110.0	212.2	325.2	478.2	0.2	0.2	0.0	0.4	1.2	0.0	11
626	1:5													
	R-TO=30	2906.0	586.3	9.7	2839.6	33.8	1.0	8.2	0.4	0.0	39.0	274.2	1.2	0.8
	R-TO=15	2654.3	888.3	11.3	5173.0	93.2	0.0	9.0	0.0	0.0	16.8	501.2	8.6	0.8
	R-TO=60	3156.8	406.2	0.0	4593.4	35.0	0.0	7.4	0.0	0.0	5.2	154.6	0.0	0
	R-TO=30	2849.6	601.7	11.2	3973.8	51.2	0.0	8.4	0.0	0.0	13.2	279.4	1.6	0.8
	TO-TO=30	200.0	200.0	200.0	188.0	243.0	600.0	0.4	1.0	1.0	8.2	15.6	10.2	20
	1:2													
	R-TO=30	3180.7	367.3	0.0	4543.2	48.0	0.0	10.4	0.0	0.0	85.8	273.0	0.0	0
	R-TO=15	2608.0	788.6	25.3	5506.4	109.4	45.6	5.6	0.0	0.0	34.4	502.2	1.6	5
	R-TO=60	2741.6	771.8	9.6	5876.2	101.0	11.6	7.8	0.4	0.0	68.8	493.6	3.2	1.2
	R-TO=30	3037.5	464.8	11.0	5203.8	51.8	5.6	8.2	0.0	0.2	56.4	270.2	0.8	0.8
	TO-TO=30	400.0	400.0	400.0	688.0	11.0	486.6	0.4	2.6	0.4	9.6	619.6	19.0	40
	1:1													
	R-TO=30	3043.4	490.6	4.0	6027.2	78.2	7.4	10.0	0.0	0.0	47.8	288.2	0.0	0.4
	R-TO=15	1829.4	1428.5	254.1	4780.4	1956.8	74.2	6.4	4.6	0.0	267.8	135.4	203.0	2.2
	R-TO=60	3103.8	442.2	0.0	5954.6	300.0	0.0	9.8	1.0	0.0	29.4	150.0	0.0	0
	R-TO=30	2121.8	1314.5	101.7	4660.8	1330.0	16.2	6.0	4.0	0.0	18.6	143.0	64.0	0.4
	TO-TO=30	600.0	600.0	600.0	893.2	1262.8	1117.6	0.2	1.6	2.8	31.8	61.0	41.0	60

APPENDIX B

Number of food-key responses, food deliveries, postponement-key responses, timeouts, and amount of time spent in timein as a function of stimulus for each pigeon in Experiment 2. Data show means from the last five sessions of each condition. Condition labels are abbreviated as follows: Baseline (BL), Partial Extinction (PE), Partial Postponement (PP), Nondiscriminated Avoidance (ND), and Nondiscriminated Avoidance with alternate time-correlated stimuli (ND ALT). See text for other details.

Pigeon	Condition	Timein (s)			Food-Key Responses			Food Deliveries			Postponement-Key Responses			Timeouts
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	
2875														
	BL	1972.1	1295.7	141.1	627.4	303.4	5.4	9.2	4.8	0.2	9.2	142.2	49.2	2.0
	PE3	1978.9	929.8	90.1	1525.6	269.8	14.0	10.6	1.2	0.4	8.2	185.4	12.6	9.0
	PP3	1737.1	898.9	168.3	1599.8	332.6	85.8	6.4	2.8	0.4	7.2	158.2	17.2	12.8
	PP2+3	402.2	417.8	410.1	193.0	180.2	255.6	0.8	0.8	2.0	0.2	3.6	2.6	39.8
	BL	2189.2	1274.3	37.5	2107.4	240.4	1.8	11.0	1.6	0.0	16.0	200.6	15.4	0.6
	PP2	1700.0	1459.6	282.3	1748.4	602.0	14.8	7.4	5.0	0.0	13.6	68.6	97.2	1.6
	ND	817.0	534.9	375.1	550.6	412.8	325.0	3.8	2.4	0.6	41.6	19.2	13.2	30.8
	BL	1842.8	1418.9	225.3	1941.4	750.2	21.0	9.8	3.2	0.0	13.2	101.8	77.6	0.8
	ND	690.1	509.0	394.0	352.6	294.0	221.8	3.6	2.4	0.4	21.0	15.4	11.0	33.4
	BL	1694.3	1334.1	252.3	1030.4	460.6	18.2	7.6	4.4	0.0	20.6	89.2	73.6	4.4
	ND ALT	617.9	488.8	384.6	390.2	395.0	339.0	4.6	1.8	1.8	15.4	11.8	8.0	35.0
910														
	BL	1378.8	1343.7	478.3	2026.8	1494.6	44.0	4.0	3.4	0.0	2.8	4.8	125.0	6.4
	PE3	571.7	412.7	375.2	546.0	598.2	756.8	2.2	1.2	1.0	15.6	10.6	2.0	37.4
	BL	1328.5	1262.9	447.9	1188.4	1054.0	85.8	4.0	3.8	0.4	12.0	7.2	113.4	9.0
	PP3	619.4	405.7	370.5	590.8	764.2	906.0	1.8	0.8	1.6	26.0	10.6	0.2	37.0
	PP2+3	443.5	433.4	405.0	244.4	554.0	678.0	1.6	1.4	1.2	8.0	12.4	1.4	39.0
	PP2	486.0	457.1	386.3	500.4	746.6	851.2	2.4	1.6	1.0	13.8	16.8	2.2	37.8
	PE1+2	984.4	975.4	519.3	1348.2	1432.8	451.2	2.8	1.8	1.6	6.6	5.4	79.2	18.8
	BL	1086.4	1032.9	505.7	1525.0	1487.8	482.8	2.2	2.6	1.0	5.4	3.2	86.0	16.0
	ND	675.6	408.5	366.9	738.2	514.0	456.8	2.4	1.4	0.4	40.4	10.2	1.4	36.0
	BL	1252.2	1131.0	484.8	1523.0	1227.2	422.8	2.4	3.6	2.0	18.6	7.8	98.4	11.8
	ND	638.7	440.1	375.9	545.6	442.4	403.6	1.8	0.8	0.8	28.8	10.0	3.6	35.8
1046														
	BL	1442.6	1133.8	279.8	1527.2	1174.8	139.4	6.4	2.8	0.0	4.2	54.4	75.8	12.0
	PE3	1302.4	551.7	248.0	1536.2	590.2	194.0	4.8	1.2	0.4	0.8	104.4	13.2	24.8
	BL	1060.7	644.8	292.0	1247.8	761.0	321.6	2.8	1.4	0.8	1.6	67.6	10.0	27.0
	PP3	826.2	491.0	338.3	873.4	645.8	387.8	3.4	1.8	0.4	0.2	49.2	4.6	32.6
	PP2+3	404.5	417.3	419.9	210.8	572.2	396.4	1.0	0.8	1.6	0.2	11.4	8.4	39.6
	BL	932.4	899.3	334.1	644.6	1156.8	269.4	1.8	2.6	0.6	10.8	2.4	64.6	24.0
	ND	422.2	411.8	402.5	41.0	169.2	281.4	0.2	0.4	0.2	1.8	1.0	1.0	39.2
	BL	1204.9	1052.1	326.4	1014.8	884.6	187.8	3.8	2.4	0.2	7.6	22.2	77.6	16.8
	ND	479.4	424.7	395.7	87.6	189.4	259.6	0.2	1.6	0.2	9.4	2.6	2.6	38.4